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Description

This invention relates to electrostatic pumps suitable for pumping relatively non-conducting liquids.

In our published European Patent Application No. 80303705 EP—A—0029301 we describe an electrostatic liquid spraying system using an electrostatic pump. The pump comprises an injection electrode with a sharp point or edge for injecting charge carriers into the liquid and downstream thereof a collector electrode of opposite polarity for taking up said injected charge carriers. Electrostatic forces acting on the injected charge carriers set up pressure which transports the liquid from the first to the second electrode without any moving mechanical parts. The charge carriers are probably ions of some kind; for convenience, they are hereinafter referred to as 'ions' but this is not to be understood as any restriction on the physical nature of the charge carriers.

The system described, though very elegant in principle, is found to have certain defects in practice. Over extended periods of use, the pump pressure is generally found to vary, typically decreasing, in a not fully predictable way. The electric current used by the pump depends on the resistivity of the liquid being pumped; at resistivities of the order of 10^{10} ohm centimetres it is acceptable, but increases rapidly as resistivity drops to 10^{8} ohm centimetres, wasting energy and producing unwanted heat. Also, the pump is found to be prone to electrical breakdown by the establishement of an ionised charge pathway between the two electrodes. Such a pathway, once established, is not easy to remove, and it may produce gas bubbles which block the pump mechanically.

We have now devised an improved form of the pump disclosed in EPO published Patent Application No. 80303705 which is able to overcome a number of the difficulties outlined above.

According to the present invention we provide an electrostatic pump for pumping liquids having a resistivity in the range 10^{10} to 10^{7} ohm cm comprising a housing said housing containing:

a passageway for liquid to be pumped through said housing:

a single injection electrode disposed in an upstream position in said passageway, said electrode having a sharp conductive tip;

a discharge electrode disposed in a downstream position in said passageway, and

means to provide an electrical connection from a high voltage generator to the injection and discharge electrode for maintaining an electrical potential of the order of kilovolts therebetween;

said pump having a constriction in the region of and downstream of the tip of said injection electrode so shaped as to conform to the surface configuration of said tip and to provide an orifice of reduced cross-section downstream of the tip, whereby liquid being pumped flows past the tip in laminar non-turbulent flow and on through the orifice, such that liquid in said orifice functions as a current limiting resistance; and

a chamber disposed downstream of the constriction and of larger cross-section than said constriction, the discharge electrode being disposed in said chamber and separated by the chamber and the constriction from the injection electrode.

The electrode tip may be in the form of a point or an edge or any other shape which is efficient for the generation of charge carriers.

The expression "of the order of kilovolts" is not intended to be narrowly interpreted and it is difficult to set precise limits because these will vary with other operating parameters. In practice it has been found under the conditions so far explored that most useful results are obtained within the range from about 3 kv to about 100 kv. Below the range pumping action begins to fall of whilst above the range although pumping action is theoretically possible problems of dielective breakdown begin to occur.

The expression "downstream" is with reference to the intended direction of flow through the pump in use.

Specific embodiments of the invention will now be described with reference to the drawings, in which:

Figure 1 is an axial section through a pump according to the invention;

Figure 2 is a radial section along the line A—A of Figure 1;

Figure 3 is a circuit diagram for the pump of Figures 1 and 2;

Figure 4 is a graph of "back-off" distance against pumping pressure for various pumps according to the invention;

Figure 5 is a graph of pumping pressure against voltage for a further pump according to the invention;

Figure 6 is a schematic diagram of three pumps of the type shown in Figures 1—3 arranged to operate in series;

Figure 7 is a schematic diagram of three pumps of the type shown in Figures 1—3 arranged to operate in parallel;

Figure 8 is a longitudinal section through a pump according to the invention having a blade electrode;

Figure 9 is a section along the line B—B of Figure 8;

Figure 10 is a longitudinal section through a further pump according to the invention;

Figure 11 is an axial section through a spraying container encorporating a pump according to the invention;

Figure 12 is an axial section through part of the holder for the container of Figure 11;

Figure 13 is a circuit diagram for the holder of Figure 12;

Figure 14 is a longitudinal section through an alternative electrode assembly for use in the pump of Figure 10; and

Figure 15 is a longitudinal section through a modified pump according to the invention.

The pump shown in Figures 1 and 2 comprises a tubular body 10 of rigid insulating plastics material (e.g. nylon or polyacetal) and having an internal diameter of about 2 mm. The upstream end 12 of the body 10 is formed with an internally threaded collar 13 to receive an injection electrode assembly 14. The electrode is of mild steel, in the form of an externally threaded cylinder 16 terminating at the downstream end in a right cone 18 (apex angle 36°), the tip 20 of which is ground to a sharp point 21. The upstream end of electrode assembly 14 has a slot 22 which may be used to screw the electrode into the collar 13 to varying distances. Two diametrically opposed grooves 24 are formed in the threaded surface of cylinder 16, to act as conduits to deliver liquid to the interior of body 10. Body 10 is formed with an internal bush 26 dividing body 10 into an upstream chamber 28 and a downstream region including chamber 30. Bush 26 is integral with body 10, and is formed with a constriction including a central conical recess 32 which receives cone 18 of the electrode assembly 14. The shape and size of conical recess 32 corresponds closely to that of cone 18, except that the cone apex angle of recess 32 is slightly greater (40°). At the centre of bush 26 is a cylindrical orifice 34, 0.2 mm in diameter and 0.2 mm in length, which allows liquid to pass from upstream chamber 28 to downstream chamber 30. In downstream chamber 30, a bush 36 of insulating plastics material forms a housing for a smooth metal bush 38 which is spaced away from the exit of channel 34 and which acts as a discharge electrode. The system is provided with a battery-powered variable high voltage generator 40, capable of producing up to 40 KV at 50 microamps. The circuit is illustrated in Figure 3; one terminal 42 of generator 40 is connected to injection electrode assembly 14, the other terminal 44, to discharge electrode 38 and to earth. A switch 46 controls the supply of power from the batteries 48 to generator 40.

In operation, liquid (e.g. a solution of an insecticide in an organic solvent, having a viscosity of 8 centistokes and a resistivity of 1 to 10^8 ohm centimetres—both measured at 25°C) is introduced into chambers 28 and 30 through grooves 24. Switch 46 is turned on, to activate the generator 40 at a voltage of, say, 20 KV. This sets up a powerful voltage gradient between point 21 of electrode assembly 14 and liquid in chamber 30. Ions are injected from point 21 and attracted through channel 34 to liquid in chamber 30, being ultimately discharged at electrode 38. This produces a steady pumping action. Liquid in channel 34 functions as a high resistance, limiting electric current flow.

Provided that a high potential difference is maintained between electrode assembly 14 and discharge electrode 38 it has been found that it does not matter which is at high potential and which is earthed. In some arrangements e.g. those in which the discharge electrode is adjacent to an electrostatic sprayhead it may be found convenient for both electrode and sprayhead to be maintained at similar high potentials.

Pressure obtainable by pumps of the type described above can be up to 1 atmosphere, though this depends on the pump dimensions, the voltage applied and liquid being pumped (de-gassed liquid works best), and also, most importantly, on the positioning of the point 21 of the injection electrode assembly 14. Figure 4 is a graph of "back-off distance" (axial displacement of the tip of the electrode back from the orifice against pumping pressure for pumps of the type illustrated. Using a liquid of resistivity 4.4×10^8 ohm cm at 25°C, an applied voltage of 17 KV and constriction diameters (channel 34) of 0.35 to 0.895 mm, static pumping pressures of up to nearly 1 metre (equivalent water head) were obtained with the maximum head being obtained at back-off distances of between about 0.1 and 1.0 mm. Figure 5 shows a graph of potential in kilovolts against static head obtained, over a range of from 0—50 KV, using the same liquid as in Figure 4 with a constriction 0.3 mm long, 0.6 mm diameter and a back-off distance of 1.0 mm. Greater back-off distances, e.g., up to 10 mm or more, may be found useful in certain circumstances.

It will be seen from the foregoing that the dimensions of the channel 34 and the back-off distance are significant parameters of our device. In the light of the information given, suitable dimensions for any desired application may readily be determined by simple experiment, but for the applications we have tried so far we find in general that suitable dimensions for the channel 34 are in the range of about 0.1 to 1 (particularly around 0.2) mm diameter and 0.1 to 5 (particularly around 0.2 to 0.3) mm length; and a back-off distance in the range of about 0.25 to 3 (particularly about 0.4 to 1.0 mm). These ranges are not necessarily limiting. Liquids of lower resistivity may require relatively longer or narrower constricting passages, or both, while a greater back-off distance may be found to work better with a shorter or wider constriction.

In general, the pump is most suitable for pumping liquids with resistivities in the range from about 10^{10} to 10^7 ohm cm, and it may not be found to work well, or even at all, with some liquids outside these resistivity ranges. The pump is particularly suited for use in electrostatic sprayers, but may also find other uses. Multistage pumps may be constructed, to run in series (as in Figure 6 where the injection electrodes of the second and third stages of the pump serve as discharge electrodes for the preceding stage) or in parallel (as in Figure 7), or in combinations of the two. Instead of an electrode with a sharp point opposite a cylindrical passage, there may be provided an electrode with a conductive edge, a blade 6 having a sharpened edge 7 placed opposite a slit 8, as shown in Figures 8 and 9.

It is not necessary that the injection electrode assembly be constructed completely of conductive material, and indeed for certain purposes it is advantageous that it should not be. When spraying dispersions (e.g., of finely-divided insoluble pesticides) it is found that interactions may occur between the

charged surface of the injection electrode and the particles of the disperse phase, which can diminish the pumping effect and make it unreliable. Such effects are lessened by making only the tip of the injection electrode assembly conductive. Figure 10 shows a section through a pump having an electrode assembly 53 of pencil-like construction, with a central conductive core 55 of graphite sharpened to a point 57, embedded axially in a cylinder 59 of non-conductive plastics material. The shape of electrode assembly 53 and of other parts of the pump, and the electrical circuit, are otherwise the same as in Figures 1—3. It is found that this arrangement pumps dispersions more reliably than the pump shown in Figures 1—3.

A wide range of conducting materials may be used for the conducting parts of the electrode assembly with acceptable performance. It is preferred to use materials which are resistant to corrosive-type attack under conditions of storage and use for example stainless steels.

Wherever possible, the body of the pumps of our invention should be of integral construction. Otherwise charge may leak through cracks from one chamber to the other. Thus the construction shown in Figures 1 and 11 is to be preferred to that shown in Figures 7—10.

One useful application for the pump according to the invention is illustrated in Figures 11 and 12. These show a pump 50 according to the invention mounted in a container 52 for electrostatic spraying of pesticides. The container comprises an insulating polyethylene terephthalate body 54, formed by blow-moulding, the neck 56 of which is fitted by means of screw threads with a nozzle 58 of conducting plastics (nylon filled with carbon black). Within nozzle 58, the base of neck 56 is closed by a disc 60 of insulating polyacetal. In the centre of disc 60 an aperture 62 carries a long thin but rigid PTFE plastics pipe 64 serving as an air inlet. In one side of disc 60 a second larger aperture 66 houses a pumping element 68 according to the invention. This comprises a metal electrode assembly 70 supported in an insulating (PTFE) plastics tubular housing 71 having its downstream end 72 flush with the outer surface of disc 60. The electrode assembly 70 terminates in a cone 73 having a sharp point 74 opposite a narrow passage 76 (length 0.2 mm, diameter 0.2 mm). The housing 71 forms a conical recess 78 of angle 40° around the cone 73 of angle 36°, thereby providing a smoothly tapered liquid channel for leading liquid into passage 76. On the upstream end 80 of housing 71 is secured a readily flexible plastics tube 82 of length slightly less than the depth of container 52. Around the inlet end 84 of tube 82 is secured a thick metal bush 86 serving as a sinking weight. A thin metal wire 88 running along the inside of tube 82 maintains electrical contact between electrode assembly 70 and bush 86. Metal studs 92 spaced apart in body 54 are electrically connected to each other by wires 94 and also to an external electrical contact 96 (the same function could be performed by a metallic strip down one side of body 54).

Nozzle 58 consists of inner and outer tubes 98 and 100 respectively, which between them form an annular channel 102 for receiving liquid from pump 68. Over part of its length channel 102 is divided into longitudinal grooves 104 by ribs 106 formed on the outer surface of tube 100. The construction of this part of the nozzle is shown in more detail in published European Application No. 51928, the disclosure of which is incorporated herein by reference. The interior of the inner tube 98 forms a liquid-tight seal with the base of disc 60, providing a pathway for air through tube 98 into pipe 64. A resilient circumferential radial flange 108 is provided on outer tube 100 to act as an electrical contact.

Adjacent flange 108, body 54 carries a screw-thread 110 which serves to mount container 52 in a spraying holder 112 shown in more detail in Figures 12 and 13. Holder 112 is provided with an elongated body 113 (only partly shown in Figure 12) serving as a handle, and with an annular neck 114 carrying an internal screw-thread 116 for mating with thread 100 and an annular metal field-intensifying electrode 117. On neck 114 are provided two electrical contacts 118 and 120 (the latter in the form of a metal annulus) which serve to contact flange 108 and contact 96 respectively. A high voltage generator 122 powered by dry cells 124 and capable of providing a voltage of 25KV at a current of 20 microamps is mounted in body 113. A conductor 126 provides an electrical connection from contact 118 to one terminal 128 of generator 122; conductor 130 connects electrode 117 to earth via a trailing earth lead 132. Conductor 133 connects electrode 117 to annular contact 120. Conductor 134 connects cells 124 with generator 122 via a push-button switch 136.

In operation, body 54 is filled with a liquid to be sprayed (for example, a 3% solution of the insecticide cypermethrin in a hydrocarbon diluent, the solution having a resistivity of 1.2 10^8 ohm cm and a viscosity of 14 m · Pa · s (centistokes), both at 25°C) and the nozzle 58 is then mounted securely on it. These are generally manufacturing operations. Prior to use, the container 52 is firmly screwed into the neck 114 of holder 112, so that flange 108 touches contact 118 and contact 96 touches contact 120. The pump 68 is then primed by pointing the nozzle 58 downwards, when hydrostatic pressure sucks air in through pipe 64 while liquid drips slowly from the end of the nozzle 58. Nozzle 58 is now pointed at the target (3 g plants) which it is desired to spray, and the switch 136 is closed. This activates generator 122 and charges nozzle 58, via conductor 126 and contact 118 to a potential of 25 KV. The potential difference thereby set up between charged liquid in nozzle 58 and earthed pump electrode assembly 70 causes pumping of liquid from body 54 into nozzle 58. Liquid at the tip of nozzle 58 is drawn out by the electrostatic field into thin threads or ligaments which break up into charged droplets of very uniform size and propelled by the field towards and onto the target.

Unlike a container having a gravity feed, this device will spray in all directions. When the container 52 is inverted, so that nozzle 58 points upwards, the weighted bush 86 falls to the bottom of the container 52, so that the mouth 84 of flexible tube 82 remains beneath the surface of the liquid, and pump 50 remains

primed. Whatever the orientation of container 52, mouth 84 is kept below the surface of the liquid until container 52 is nearly empty. The ability to spray in all directions is a substantial advantage over known containers of this type. However, a variant of the container shown, in which tube 82 and bush 86 are removed, is also useful. Though it can only spray with the nozzle 58 pointing downwards, it can have a steadier spray delivery rate than known devices relying on gravity feed. A steady spray rate is often important in agricultural applications. In another variant of container 52, pump 50 replaces bush 86 at the end of tube 82. This device primes much more easily; however a conductor wire is needed to bring high voltage along tube 82 to within a reasonable distance of the pump 50, and it is necessary to make tube 82 of highly insulating material (e.g., PTFE) or charge will leak through the tube walls.

Figure 14 shows an alternative electrode assembly for use in the pumps of Figure 1 or 10. It comprises a rigid plastics (e.g., polyacetal) body 120 having the same shape as electrode assembly 14 of Figure 1, metallised all over with a thin layer 121 (less than 1 micron thick) of aluminium or copper. Such electrode assemblies do not require to be fabricated by metal grinding techniques, but can be made in large numbers by plastics injection moulding, followed, e.g., by vacuum metallising. They do not have as long as life as metal electrodes, but are satisfactory in devices intended for only limited use.

Figure 15 shows a modified pump design having an outer casing 201 of electrically insulating polyacetal of generally cylindrical shape. An inner casing 202 of the same material is mounted within the outer casing and defines a passageway 203 for liquid to be pumped leading to a channel 204 of reduced cross-section at its downstream end.

An electrode assembly 205 of circular cross-section comprises a stainless steel (British standard EN56, a ferromagnetic alloy composition) wire 206 of diameter 0.125 mm encased in polyacetal 207 except for its downstream tip 208.

The channel 204 is shaped to conform with the conical downstream end of the electrode assembly and the downstream edges 209 of the channel are rounded off. It has been found in practice that this improves the laminar flow of liquid through the channel.

The pump casing also holds a discharge electrode 209 of carbon-loaded nylon forming part of a downstream region 211, and the pump in general functions in the same way as those described previously.

Variations in performance can be obtained by varying the dimensions and other operating parameters.

For example the following figures were obtained using a cyclohexanone/white oil formulation.

Flow rate (at zero back pressure)	12 cc/min
Pressure (at zero flow rate)	0.035 kg/cm^2 (5. psi)
Current (1×10^8 ohm · cm)	4 ua
Acceptable resistivity range of formulations	5×10^7 to 5×10^9 ohm cm
Applied voltage	up to 40 kv

In the above Example the narrowest part of the channel had a diameter of 0.35 mm and a length of 0.3 mm with an electrode "back-off" of 0.8 mm.

Further tuning of the pump can result in the further optimisation of one performance characteristic at the expense of others.

Hence a pump with a .175×.175 (mm) hole only delivers about 4.5 cc/min at 25 kV, but is capable (with degassed formulation) of developing pressures up to 15 psi (0.105 Kg/cm^2). Conversely, a pump with a larger flared hole (say, with a maximum hole diameter of .5 mm) is capable of producing flowrates up to 25 cc/m, but is only capable of developing pressures up to 1—2 psi (0.007—0.014 kg/cm^2).

Claims

1. An electrostatic pump for pumping liquids having a resistivity in the range 10^{10} to 10^7 ohm cm comprising a housing (10), said housing containing:

a passageway (28, 30) for liquid to be pumped through said housing;

a single injection electrode (14) disposed in an upstream position in said passageway (28, 30), said electrode having a sharp conductive tip (20);

a discharge electrode (38) disposed in a downstream position in said passageway (28, 30), and

means to provide an electrical connection from a high voltage generator (40) to the injection and discharge electrode (14, 38) maintaining an electrical potential of the order of kilovolts therebetween; characterised by:

a constricton (32, 34) in the region of and downstream of the tip (20) of said injection electrode so shaped as to conform to the surface configuration of said tip (20) and to provide an orifice (34) of reduced cross-section downstream of the tip (20), whereby liquid being pumped flows past the tip (20) in laminar non-turbulent flow and on through the orifice (34), such that liquid in said orifice (34) functions as a current limiting resistance; and

a chamber (30) disposed downstream of the constriction (32, 34) and of larger cross-section than said constriction, the discharge electrode (38) being disposed in said chamber (30) and separated by the chamber (30) and the constriction (32, 34) from the injection electrode (14).

2. A pump as claimed in Claim 1, in which the constriction (32, 34) has sides having an angle therebetween which is slightly more than the angle of the tip.

3. A pump as claimed in Claim 1 or 2, in which the axial displacement of the tip (21) of the electrode (22) from the orifice (34) is in the range 0.25 to 3 mm.

4. A pump as claimed in any preceding claim, in which the injection electrode (22) comprises a conducting core (55) encased in insulating material (59), the core (55) being exposed at the downstream end which forms the electrode tip (21).

5. A pump as claimed in any preceding claim, in which the injection electrode (14) comprises a conducting coating (121) on an insulating core (120).

6. A pump as claimed in any preceding claim, in which the electrically conductive tip (20) is made of material which is corrosion resistant under conditions of storage and use.

7. A pump as claimed in any preceding claim, in which the downstream opening of the orifice (34) has tapered or rounded edges to promote laminar, non-turbulent fluid flow.

8. A pump complex comprising a plurality of pumps as claimed in any of Claims 1 to 7, connected in series.

9. A pump complex comprising a plurality of pumps as claimed in any of Claims 1 to 7 connected in parallel.

10. An electrostatic spraying system comprising a pump as claimed in any one of Claims 1 to 7 adapted to deliver liquid to an electrostatic sprayhead (58).

11. A system as claimed in Claim 10, in which the sprayhead (58) and the pump are activated by the same source of high voltage.

12. A system as claimed in Claim 10 or 11, adapted for agricultural spraying.

13. A liquid container having attached to it a pump (50) as claimed in any of Claims 1 to 7, and liquid and electrical connections (58, 96) whereby the pump is capable of delivering liquid to or from the container in use.

14. A container as claimed in Claim 13, in which the pump (50) is mounted in the container (52).

15. A container as claimed in Claim 13 or 14, which is adapted to deliver liquid to a sprayhead (58).

16. A container as claimed in Claim 15, in which the sprayhead is an electrostatic sprayhead.

17. A container as claimed in Claim 16 in which the sprayhead (58) is part of the container and is electrically connectable to a source of high voltage for the sprayhead and for the pump in use.

18. A container as claimed in Claim 17, in combination with a holder (112) which includes the source of high voltage and electrical connections (118) complementary to those on the container for connecting the source to the sprayhead and the pump when the container is attached to the holder.

Patentansprüche

1. Elektrostatische Pumpe zum Pumpen von Flüssigkeiten mit einem spezifischen Widerstand im Bereich von 10^{10} bis 10^{7} Ohm cm, welche ein Gehäuse (10) aufweist, wobei das Gehäuse folgendes enthält:

einen Durchgang (28, 30) für durch das Gehäuse zu pumpende Flüssigkeit;

eine einzige Injektionselektrode (14), die stromaufwärts des genannten Durchgangs (28, 30) angeordnet ist, wobei die Elektrode eine scharfe leitende Spitze (20) aufweist;

eine Enladungselektrode (38), die stromaufwärts im Durchgang (28, 30) angeordnet ist; und

eine Einrichtung zur Schaffung einer elektrischen Verbindung von einem Hochspannungsgenerator (40) zur Injektions- und zur Entladungselektrode (14, 38), wodurch zwischen ihnen eine elektrische Spannung in der Größenordnung von Kilovolt aufrechterhalten wird; gekennzeichnet durch

eine Verengung (32, 34) im Bereich der Spitze (20) der genannten Injektionselektrode und stromabwärts derselben von solcher Form, daß sie der Oberflächenform der genannten Spitze (20) entspricht und eine Öffnung (34) mit verringertem Querschnitt stromabwärts der Spitze (20) gebildet wird, wodurch zu pumpende Flüssigkeit entlang der Spitze (20) in einem laminaren, nichtturbulenten Fluß und durch die Öffnung (34) strömt, so daß Flüssigkeit in der Öffnung (34) als ein den Strom beschränkender Widerstand wirkt; und

eine Kammer (30), die stromabwärts der Verengung (32, 34) angeordnet ist und einen größeren Querschnitt als diese Verengung aufweist, wobei die Entladungselektrode (38) in dieser Kammer (30) angeordnet und durch die Kammer (30) und die Verengung (32, 34) von der Injektionsleketrode (14) getrennt ist.

2. Pumpe nach Anspruch 1, in welcher die Verengung (32, 34) Seiten mit einem eingeschlossenen Winkel aufweist, der etwas größer ist als der Winkel der Spitze.

3. Pump nach Anspruch 1 oder 2, in welcher der axiale Abstand der Spitze (21) der Elektrode (22) von der Öffnung (34) im Bereich von 0,25 bis 3 mm liegt.

4. Pumpe nach einem der vorhergehenden Ansprüche, in welcher der Injektionselektrode (22) einen leitenden Kern (55) aufweist, der in isolierendes Material (59) eingeschlossen ist, wobei der Kern (55) am stromabwärtigen Ende, welches die Elektrodenspitze (21) bildet, freilegt.

5. Pumpe nach einem der vorhergehenden Ansprüche, in welcher die Injectionsleketrode (14) ein leitende Umhüllung (121) auf einem isolierenden Kern (120) aufweist.

6. Pumpe nach einem der vorhergehenden Ansprüche, in welcher die elektrisch leitende Spitze (20) aus einem Material besteht, das unter den Lagerungs- und Gebrauchsbedingungen korrisionsbeständig ist.

7. Pumpe nach einem der vorhergehenden Ansprüche, in welcher das stromabwärtige Ende der Öffnung (34) aufgeweitete oder abgerundete Ränder aufweist, um einen laminaren, nichtturbulenten Flüssigkeitsfluß zu fördern.

8. Pumpenkomplex, der eine Anzahl von Pumpen nach einem der Ansprüche 1 bis 7 aufweist, die in Reihe geschaltet sind.

9. Pumpenkomplex, der eine Anzahl von Pumpen nach einem der Ansprüche 1 bis 7 aufweist, die parallel geschaltet sind.

10. Elektrostatisches Sprühsystem, welches eine Pumpe nach einem der Ansprüche 1 bis 7 aufweist, die so ausgeführt ist, daß sie Flüssigkeit zu einem elektrostatischen Sprühkopf (58) liefert.

11. System nach Anspruch 10, in welchem der Sprühkopf (58) und die Pumpe durch die gleiche Hochspannungsquelle aktiviert werden.

12. System nach Anspruch 10 oder 11, welches für landwirtschafliches Sprühen angepaßt ist.

13. Flüssigkeitsbehälter, an welchem eine Pumpe (50) nach einem der Ansprüche 1 bis 7 befestigt ist und welcher Flüssigkeit enthält und elektrische Verbindungen (58, 96) aufweist, wodurch die Pumpe fähig ist, beim Gebrauch Flüssigkeit zum oder vom Behälter zu befördern.

14. Behälter nach Anspruch 13, bei welchem die Pumpe (50) im Behälter (52) angeordnet ist.

15. Behälter nach Anspruch 13 oder 14, welcher so ausgebildet ist, daß er Flüssigkeit zu einem Sprühkopf (58) liefert.

16. Behälter nach Anspruch 15, bei welchem der Sprühkopf ein elektrostatischer Sprühkopf ist.

17. Behälter nach Anspruch 16, bei welchem der Sprühkopf (58) ein Teil des Behälters ist und beim Gebrauch elektrisch mit einer Hochsprannungsquelle für den Sprühkopf und die Pumpe verbindbar ist.

18. Behälter nach Anspruch 17 in Kombination mit einem Halter (112), der die Hochspannungsquelle und elektrische Verbindungen (118) aufweist, wobei letztere denjenigen des Behälters komplementär sind, um die Hochspannungsquelle mit dem Sprühkopf und der Pumpe zu verbinden, wenn der Behälter am Halter befestigt ist.

Revendications

1. Pompe électrostatique pour le pompage de liquides ayant une résistivité dans la gamme de 10^{10} à 10^{7} ohms · cm, comprenant un corps 10, ledit corps contenant:

un passage (28, 30) pour le liquide à pomper à travers ledit corps;

une électrode unique (14) d'injection disposée dans une position en amont dans ledit passage (28, 30), ladite électrode ayant un bout conducteur effilé (20);

une électrode (38) de décharge disposée dans une position en aval dans ledit passage (28, 30); et

des moyens pour établir une connexion électrique entre un générateur (40) de haute tension et les électrodes d'injection et de décharge (14, 38), maintenant un potentiel électrique de l'ordre de plusieurs kilovolts entre elles; caractérisé par:

un étranglement (32, 34) dans la zone et en aval du bout (20) de ladite électrode d'injection, configuré de façon à se conformer à la configuration de la surface dudit bout (20) et à présenter un orifice (34) de section transversale réduite en aval du bout (20), afin qu'un liquide à pomper passe en s'écoulant sur le bout (20) en un écoulement laminaire non turbulent, puis dans l'orifice (34), de manière que le liquide dans ledit orifice (34) assume la fonction d'une résistance de limitation de courant; et

une chambre (30) disposée en aval de l'étranglement (32, 34) et d'une section transversale supérieure à celle dudit étranglement, l'électrode de décharge (38) étant disposée dans ladite chambre (30) et séparée par la chambre (30) et l'étranglement (32, 34) de l'électrode d'injection (14).

2. Pompe selon la revendication 1, dans laquelle l'étranglement (32, 34) présente des côtés formant entre eux un angle légèrement supérieur à l'angle du bout.

3. Pompe selon la revendication 1 ou 2, dans laquelle le décalage axial du bout (21) de l'électrode (22) à partir de l'orifice (34) est de l'ordre de 0,25 à 3 mm.

4. Pompe selon l'une quelconque des revendications précédentes, dans laquelle l'électrode d'injection (22) comprend une âme conductrice (55) entourée d'une matière isolante (59), l'âme (55) étant exposée à l'extrémité d'aval qui forme le bout (21) de l'électrode.

5. Pompe selon l'une quelconque des revendications précédentes, dans laquelle l'électrode d'injection (14) comprend un revêtement conducteur (121) sur une âme isolante (120).

6. Pompe selon l'une quelconque des revendications précédentes, dans laquelle le bout électriquement conducteur (20) est réalisé en une matière qui résiste à la corrosion dans les conditions de stockage et d'utilisation.

7. Pompe selon l'une quelconque des revendications précédentes, dans laquelle l'ouverture d'avail de l'orifice (34) présente des bords chanfreinés ou arrondis qui favorisent un écoulement de fluide laminaire, non turbulent.

8. Batterie de pompes comprenant plusieurs pompes selon l'une quelconque des revendications 1 à 7, raccordées en série.

9. Batterie de pompes comprenant plusieurs pompes selon l'une quelconque des revendications 1 à 7, raccordées en parallèles.

10. Système de pulvérisation électrostatique comprenant une pompe selon l'une quelconque des revendications 1 à 7, apte à distribuer un liquide à une tête de pulvérisation électrostatique (58).

11. Système selon la revendication 10, dans lequel la tête de pulvérisation (58) et la pompe sont activées par la même source de haute tension.

12. Système selon la revendication 10 ou 11, conçu pour la pulvérisation en agriculture.

13. Conteneur de liquide auquel sont fixés une pompe (50) selon l'une quelconque des revendications 1 à 7 et des raccordements liquides et électriques (58, 96), permettant à la pompe de pouvoir distribuer un liquide au conteneur ou à partir du conteneur lors de l'utilisation.

14. Conteneur selon la revendication 13, dans lequel la pompe (50) est montée dans le conteneur (52).

15. Conteneur selon la revendication 13 ou 14, qui est apte à délivrer une liquide à une tête (58) de pulvérisation.

16. Conteneur selon la revendication 15, dans lequel la tête de pulvérisation est une tête de pulvérisation électrostatique.

17. Conteneur selon la revendication 16, dans lequel la tête de pulvérisation (58) fait partie du conteneur et peut être connectée à une source de haute tension pour la tête de pulvérisation et pour la pompe lors de l'utilisation.

18. Conteneur selon la revendication 17, en combinaison avec une support (112) qui comprend la source de haute tension et des connexions électriques (118) complémentaires de celles situées sur le conteneur pour connecter la source à la tête de pulvérisation et à la pompe lorsque le conteneur est fixé au support.

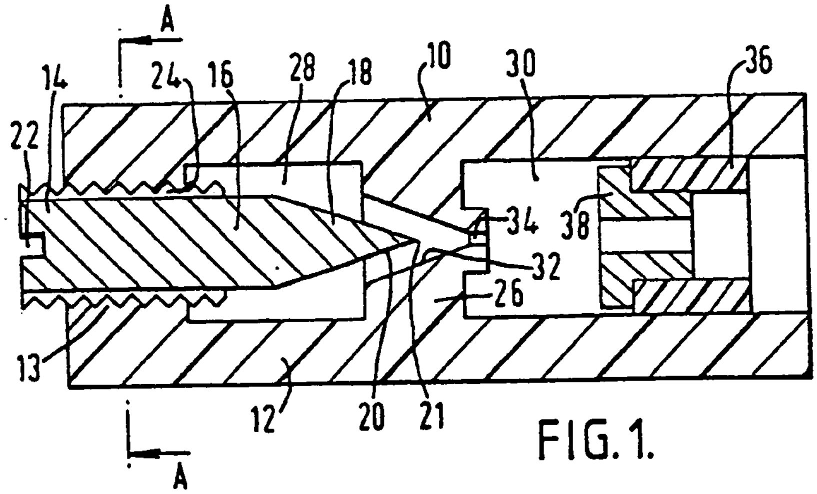


FIG. 1.

FIG. 2.

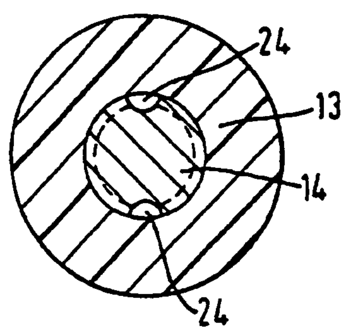


FIG. 3.

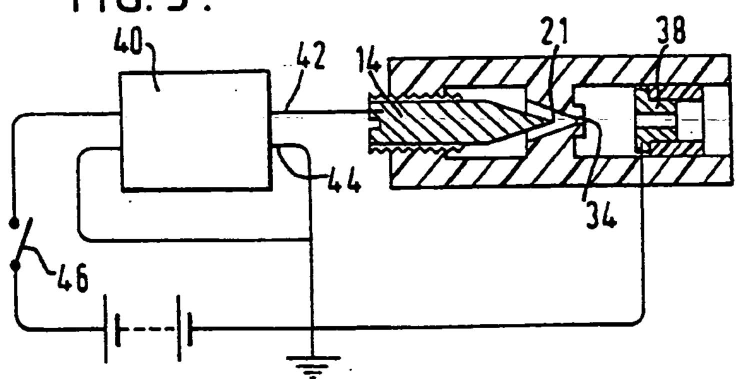


FIG. 4.

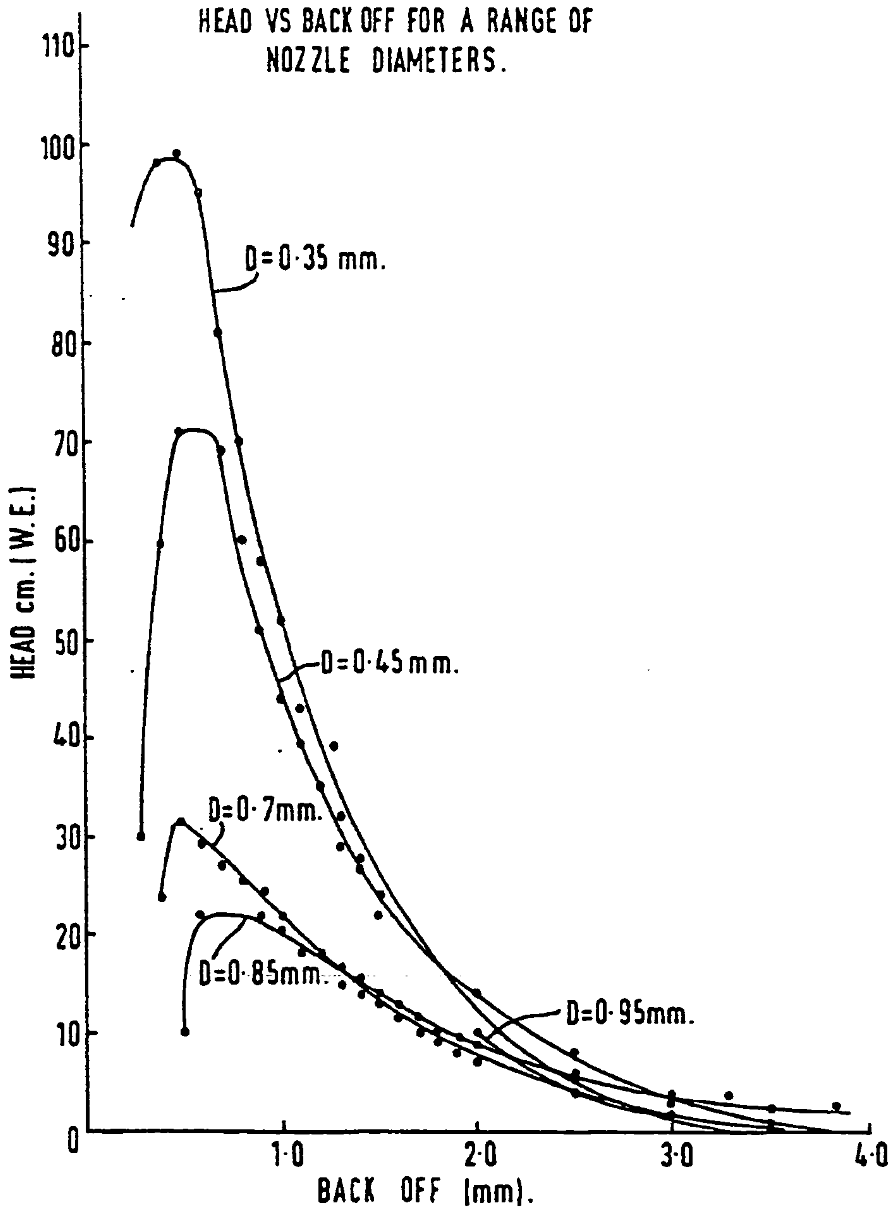
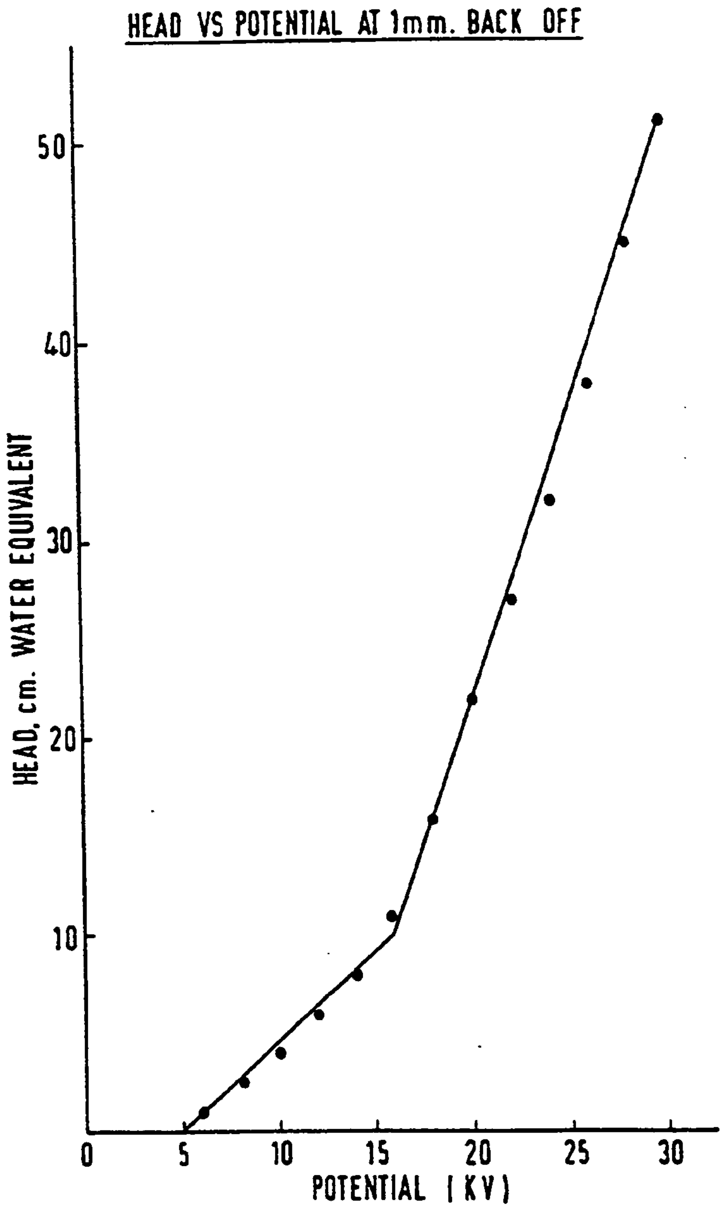

HEAD VS BACK OFF FOR A RANGE OF NOZZLE DIAMETERS.
HEAD cm. (W.E.)
110
100
90
80
70
60
50
40
30
20
10
0
D=0·35 mm.
D=0·45 mm.
D=0·7mm.
D=0·85mm.
D=0·95mm.
1·0
2·0
3·0
4·0
BACK OFF (mm).

FIG. 5.


HEAD VS POTENTIAL AT 1mm. BACK OFF
HEAD, cm. WATER EQUIVALENT
50
40
30
20
10
0
5
10
15
20
25
30
POTENTIAL (KV)

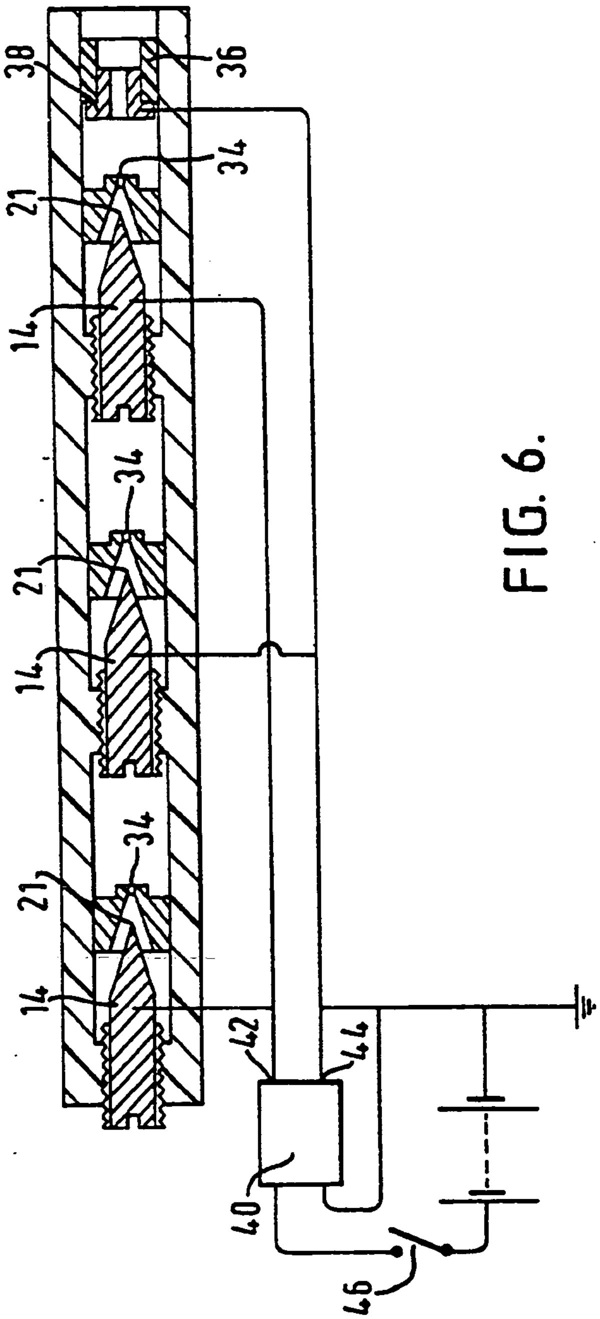


FIG. 6.

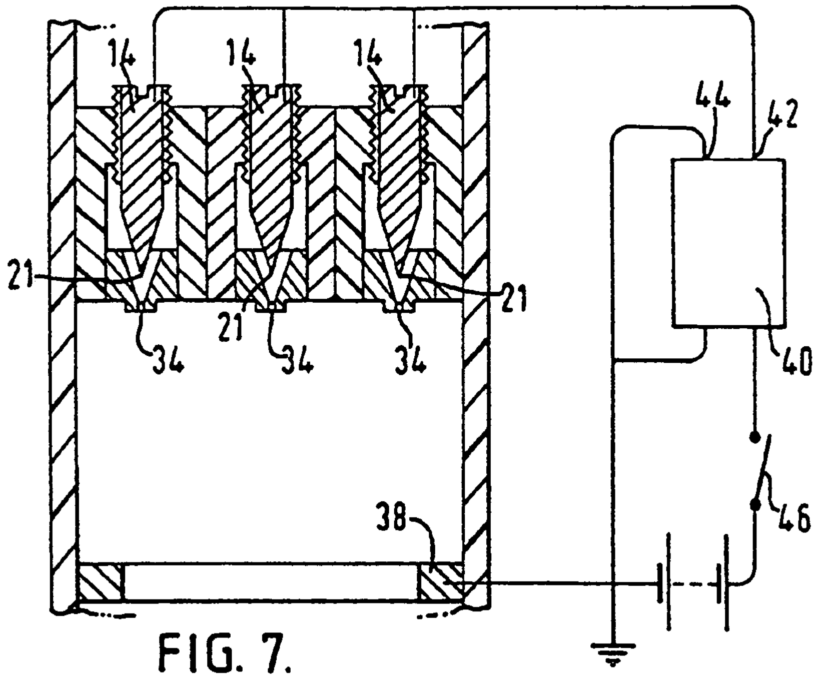


FIG. 7.

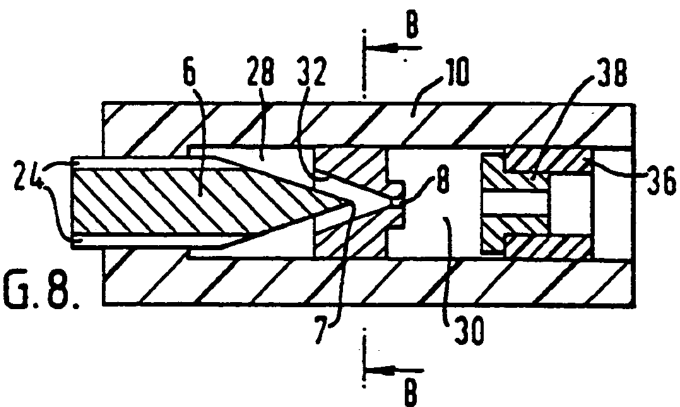


FIG.8.

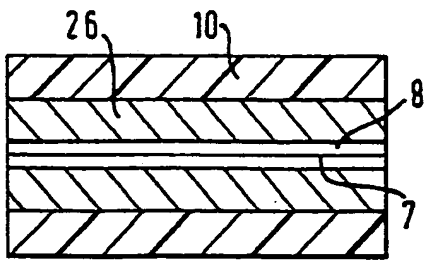


FIG.9.

FIG. 10.

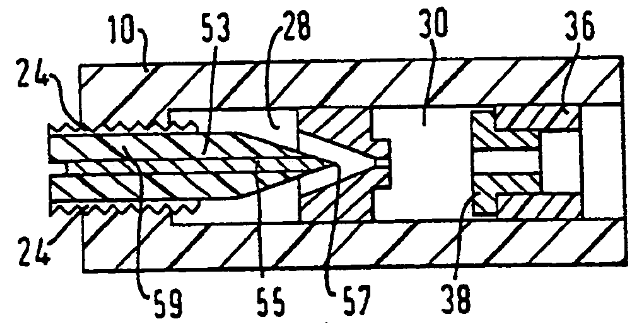


FIG. 12.

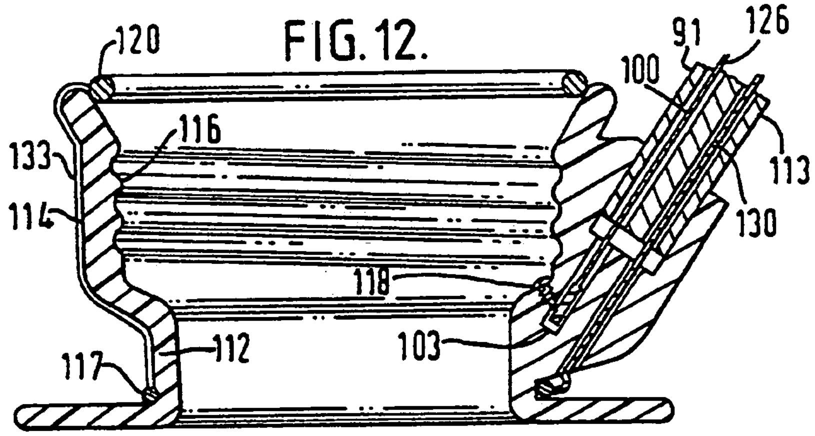


FIG. 13.

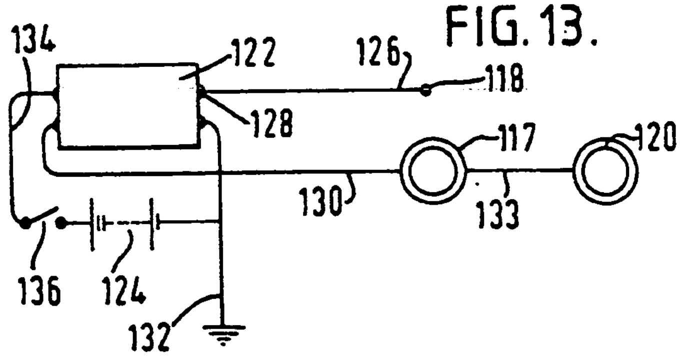
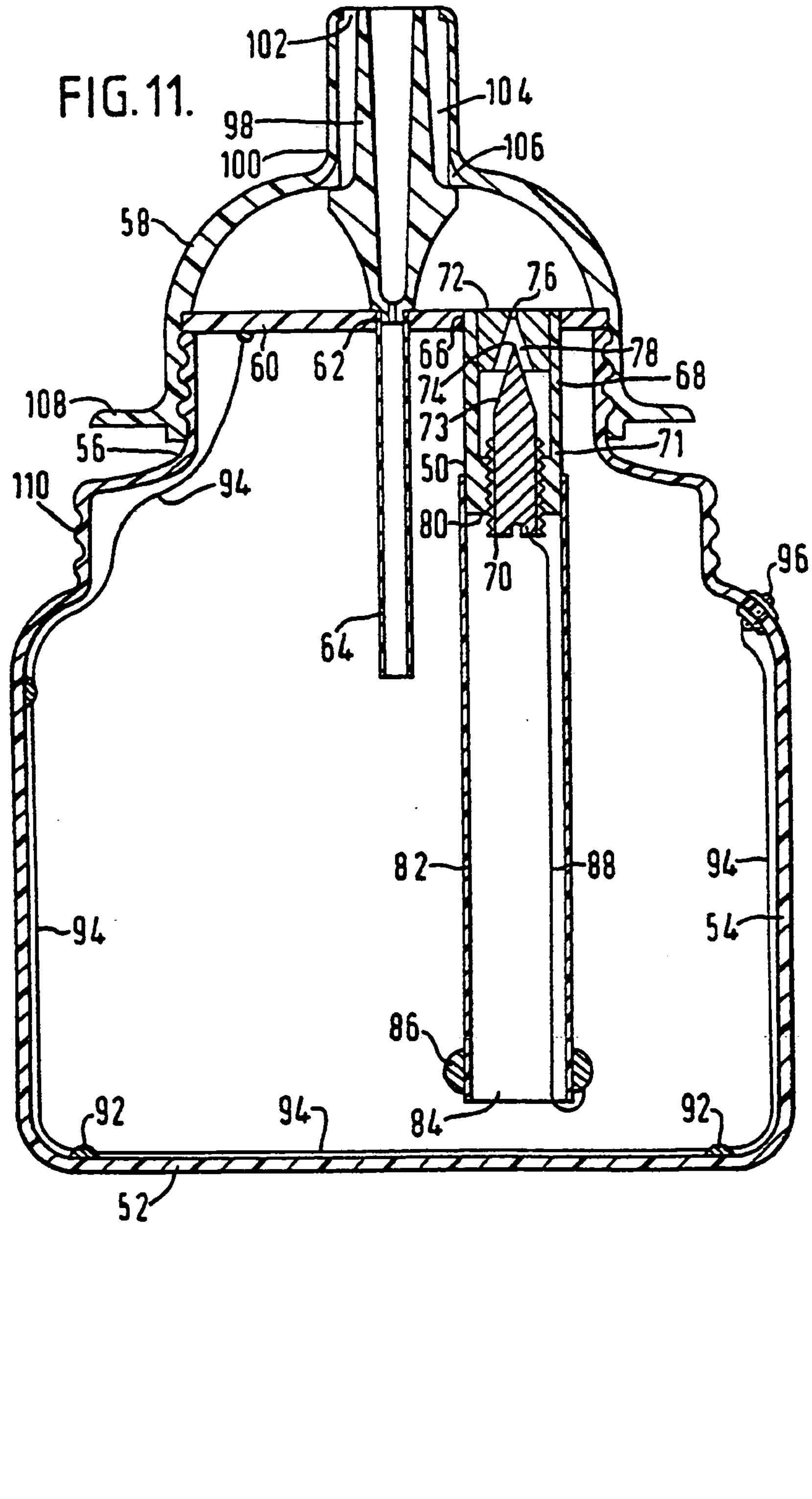


FIG. 11.



102
104
98
100
106
58
72
76
60
62
66
74
78
68
108
73
56
71
50
110
94
80
70
96
64
82
88
94
54
94
86
92
94
84
92
52

FIG. 14.

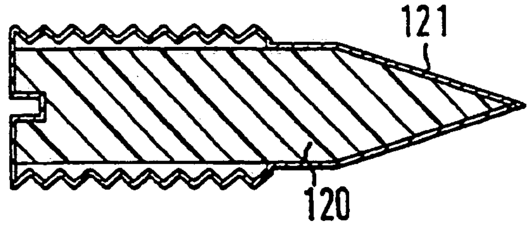


FIG. 15.